

LSST Data Simulation and Algorithm Development Plans

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In collaboration with...

- Kem Cook
- Dave Dearborn
- Mark Huber
- Kevin Schlaufman

Research Activities: Overview

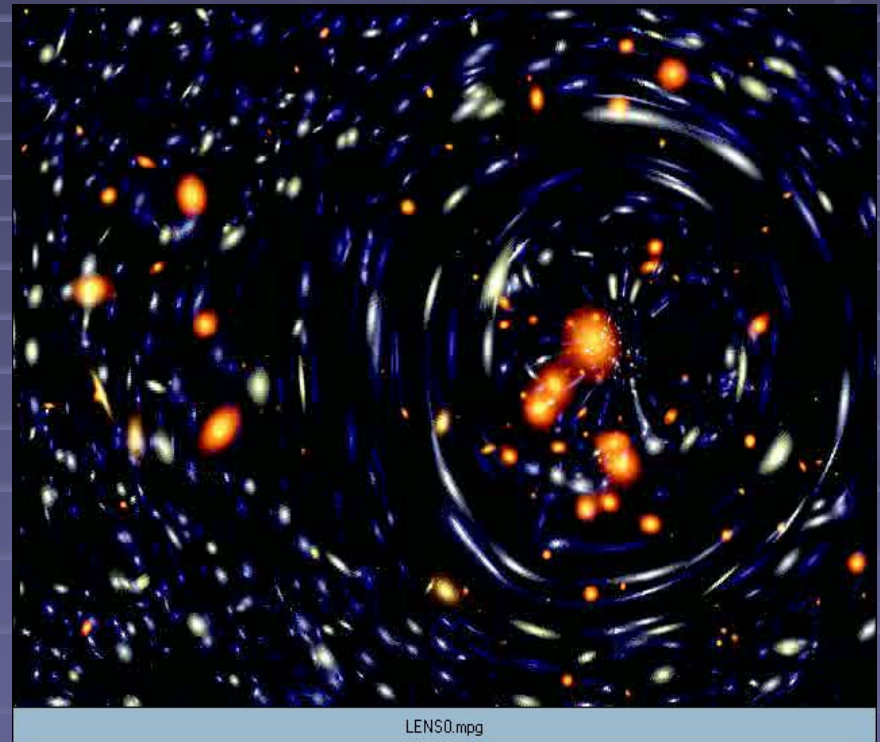
- Data Simulation
 - Weak lensing simulation: sky to CCD
 - LSST focal plane: MACHO image stitching
- Algorithm development: pipeline
 - PSF fitting
- Algorithm development: science
 - Asteroid linkage problem
 - Connection to data simulation

Data simulation

- Need artificial images to match the LSST specs (seeing, exposure time, FOV, depth, etc.)
- Goal: to test various components of the LSST image processing pipeline to
 - resolve performance bottleneck issues
 - perfect the algorithms
 - design data structures
 - optimize data mining
- Bottom line: need to have a well-designed and fast pipeline even before telescope's first light!

Weak lensing simulations (sky to CCD)

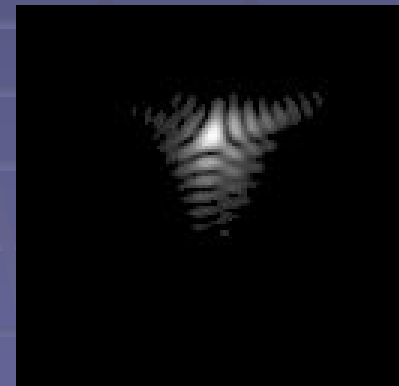
- Weak lensing probes distribution of dark matter
- Need to reconstruct shapes of galaxies above the atmosphere
- Requires knowledge of PSF shape across the FOV
- PSF shape is affected by atmosphere & telescope optics
- Simulations of the atmospheric turbulence are being conducted (Kevin Schlaufman)



Strong lensing example to show the 'shear' effect.

Weak lensing simulation (cont'd)

- Focus on atmospheric effects (turbulence, scintillation, wind speed)
- Several software packages exist
 - Arroyo (Caltech)
 - Wave Train
 - Keck AO simulator (LLNL)
- Compute PSF on a grid in FOV; interpolate between grid nodes
- Telescope optics will be added later



MACHO image stitching

- Another way to simulate LSST focal plane
- 20 MACHO images = 1 LSST FOV
- Requires matching of PSF at the edges
- Sky uniformity problem
- Sample distribution of seeing (~ 100 LSST FOVs)

Data pipeline

- Many image processing pipelines share similar components (tasks), e.g.
 - Calibration frames
 - WCS solution
 - Image subtraction
- Modify existing SuperMacho pipeline: complex code written in C, Perl, Python
- SuperMacho dubbed 'LSST precursor': multi-CCD deep time-domain survey
- Incremental changes/optimizations





Data pipeline (sandbox model)

- LLNL has rich experience in time-domain astronomy and pipeline development
 - MACHO
 - SuperMACHO
 - LONEOS
 - LOTIS
 - TAOS
- Goal: versatile pipeline (LSST + others)
- Fast (support real-time processing)
- Developing fast algorithms

Pipeline: Algorithms

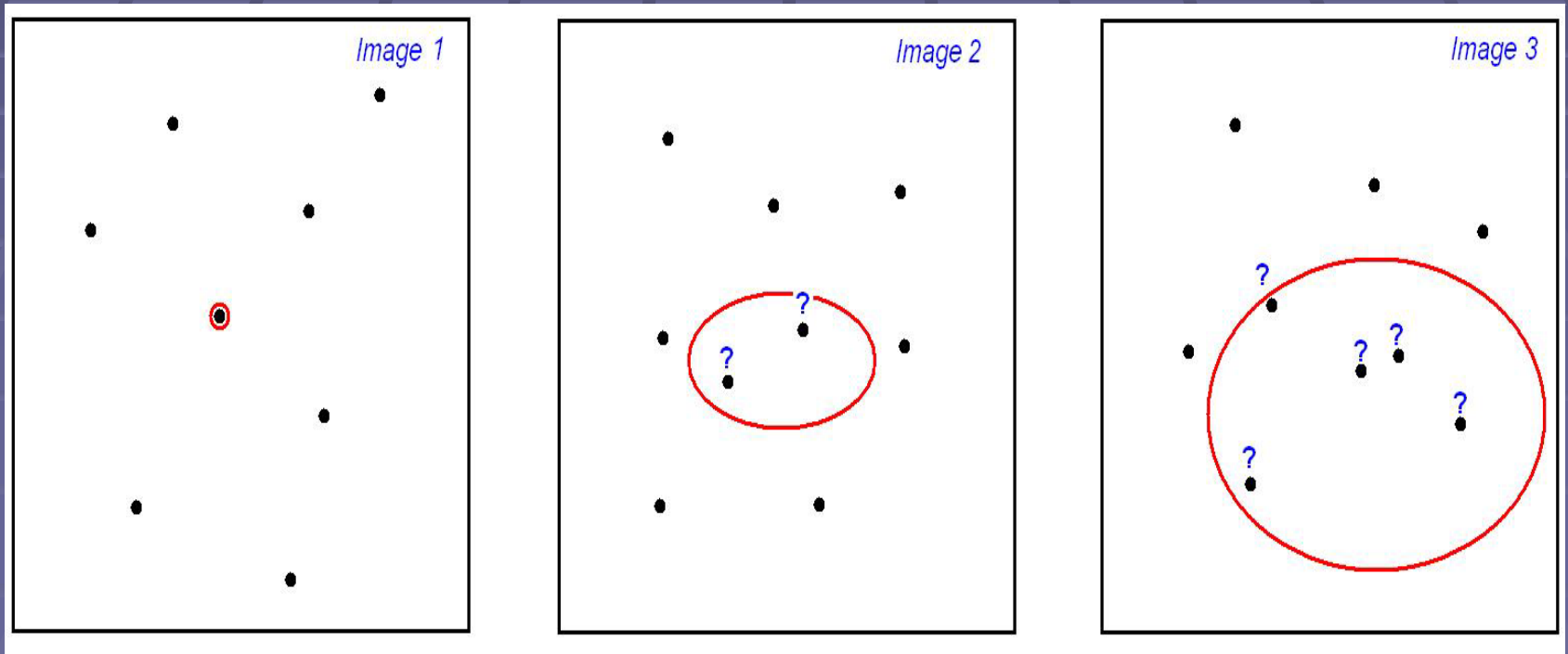
- PSF fitting algorithm (Pixie)
- Developed for SuperMacho pipeline
- Standalone C++ application
- ~10x faster than DoPHOT
- Similar quality of the photometry
- Continuing improvements

Asteroid linkage problem

- Moving objects: pop up in difference images
- Main belt @ ecliptic: 1000 objects/square deg (<24 mag)
- Moving 10'-15' per night
- Patterns do not stay constant (old ones may leave; new ones may come in)
- The main problem is confusion!!!

Asteroid Linkage Problem (cont'd)

- Need 3 observations to derive orbit elements
- Most asteroids (>90%) are in the main asteroid belt (2.5-3.5 AU); in ecliptic plane ($i \sim 0$), on circular orbits ($e \sim 0$)
- Probability ellipse for each object in original image



Asteroid linkage problem (cont'd)

- Combinatorial problem $C(N,3)$
- Remove certain non-asteroids first to reduce N
- Need to do fast fitting for orbits
- Magnitude is a weak filter
 - Short-term variations (rotation) ~ 0.3 mag
 - Long-term variations (distance) - larger
- Current LSST scheduling strategy driven by asteroid linkage problem (image pairs, $\Delta t \sim 15$ min)
- Looking to relax the strategy algorithmically

Asteroid Linkage Problem (cont'd)

- Multi-pass orbital solution algorithm
 - 1) main belt
 - 2) NEA (check for streaks or elongated PSF)
 - 3) increase probability ellipse to include more candidates
- Need 3 observations minimum
- Solution may not be unique: may need 4th or 5th observation (tie-breaker)
- Earth-crossing asteroids may need short Δt

Pipeline/data requirements

- Storage for 5 nights of objects lists per field
- Data structure should include t, RA, Dec (+potentially PSF elongation)
- Database for asteroids with solved orbits (to interact with candidates)
- Input data cleaned from known stars (non-moving)
- Hardest performance hit @ beginning of survey (many new objects); decrease as more orbital solutions are found

Connection to data simulation

- Using MACHO bulge data
- $T = 8$ years; typical $\Delta t = 2$ days
- Some fields have additional short Δt
- Fields near ecliptic; many asteroids
- Can test asteroid linkage algorithm on MACHO data
- Test if can relax short Δt requirement

Summary

- LLNL hard at work on LSST problems
 - Data simulation
 - Algorithms (pipeline & science)
- Building on previous experience
- Uniquely qualified personnel to interface CS and astronomy